

5 IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

To the Commissioner of Patents and Trademarks,

10 Your petitioner, Paul W. McBURNEY, a citizen of the
United States and a resident of San Francisco, California,
whose post office address is 571 Second Avenue, San Francisco,
CA 94118; Arthur WOO, a citizen of the United States and a
resident of California, whose post office address is 21577
Villa Maria Court, Cupertino, CA 95014; and France RODE, a
15 citizen of the United States and a resident of Los Altos,
California, whose post office address is 298 La Cuesta Ave.,
Los Altos, CA 94024, prays that letters patent may be granted
to him for a

20 COMBINATION NAVIGATION SATELLITE
RECEIVERS AND COMMUNICATIONS DEVICES

as set forth in the following specification.

COMBINATION NAVIGATION SATELLITE
RECEIVERS AND COMMUNICATIONS DEVICES

5 1. Field of the Invention

 The present invention relates to combinations of navigation satellite receivers and communication devices, and more particularly to sharing crystal oscillators between GPS receivers and cellphone handsets.

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2. Description of the Prior Art

 Most consumer electronic devices are mass produced and their sales are very dependent on how they are priced. One way to offer better prices is to reduce manufacturing costs, e.g., the cost of labor and the components used. Combinations of navigation satellite receivers and communication devices are now available, and many conventional commercial products provide one set of crystals and crystal oscillators for the navigation satellite receiver part, and a separate set for the communication devices.

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 One of the present inventors, Paul McBurney, together with some others, have recently filed several United States Patent Applications for inventions relating to GPS receivers. These are summarized in Table II. All such patent applications have been assigned to the same Assignees, and are incorporated herein by reference.

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TABLE II

Docket No.	Title	Inventors	USPTO Filing	USPTO Serial No.	U.S. Patent
734-01	Navigation satellite receiver and Method of	P.McBurney, A.Woo	11-Oct-00	09/687,044	6,437,734 08-20-02
734-02	Infrastructure-Aiding for Satellite Navigation satellite receiver and Method	P.McBurney, A.Woo	28-Feb-01	09/797,521	6,473,030B1 10-29-02
734-03	High sensitivity GPS Receiver and Reception	P.McBurney, A.Woo	19-Feb-02	10/079,245	
734-04	Total Correction Strategy	Stephen J, Edwards, P.McBurney	19-Feb-02	10/079,217	
734-05	Method and System for Position Calculation from Calculated Time	S.Edwards, P.McBurney	19-Feb-02	10/079,244	
734-06	Computing Network Path Delays so Accurate Absolute Time can be Forwarded from a Server to a Client	H.Matsushita, P.McBurney	19-Feb-02	10/079,251	
734-07	No Preamble Frame Sync	Akira Kimura, P.McBurney	19-Feb-02	10/079,250	
734-08	Thin Client	P.McBurney, C.Rasmussen, F.Vaucher, K.Victa	19-Feb-02	10/079,249	6,584,404 6-24-03
734-09	Software Crystal Oscillator	H.Matsushita, P.McBurney	19-Feb-02	10/079,248	6,509,870B1 01-21-03
734-10	High Sensitivity Infrequent Use of Sensors	P.McBurney, K.Victa	19-Feb-02	10/079,247	6,559,795 5-6-03
734-11	Real Time Clock (RTC)	P.McBurney	19-Feb-02	10/079,253	
734-12	Shared Reference Station	C.Rypinski, M.Junkar	19-Feb-02	10/079,252	
734-13	Client-Aided Doppler Estimation	P. McBurney, W.J. Morrison	07-Aug-02	10/215,138	
734-15	Synthetic Nav-Data For A High-Sensitivity Satellite Positioning System Receiver	P. McBurney, W.J. Morrison	not yet filed		

There is a need for a less expensive-to-produce
5 combination of a navigation satellite receiver and a
communication device.

SUMMARY OF THE INVENTION

Briefly, a combination of a navigation satellite receiver and a communication device embodiment of the present invention
5 exchanges precise synthesized frequencies and clocks between the navigation satellite receiver and the communication device. In one embodiment, a TCXO crystal serves as a reference for the navigation satellite receiver and locking onto the satellite transmissions allows highly accurate
10 frequency synthesis and clock generation by it for the communication device. In another embodiment, a VCO primarily affiliated with the communication device serves as a basic reference for the navigation satellite receiver, and subsequent locking onto the satellite transmissions again
15 allows highly accurate frequency synthesis and clock generation for the communication device. In a further embodiment, a VCO primarily affiliated with the communication device serves as a basic reference for the navigation satellite receiver after it locks onto the communications
20 systems standards. The navigation satellite receiver therefore has reduced clock uncertainty and can initialize and track satellites much faster than otherwise.

An advantage of the present invention is that a system and method is provided for a navigation receiver to operate
25 accurately with less than a full ephemeris for any particular GPS satellite.

These and other objects and advantages of the present invention will no doubt become obvious to those of ordinary skill in the art after having read the following detailed
30 description of the preferred SPS receivers which are illustrated in the various drawing figures.

IN THE DRAWINGS

Fig. 1 is a schematic diagram of a combination GPS
satellite navigation receiver part and communication device
5 system embodiment of the present invention in which the
communication device's VCO provides a reference frequency
assist to the GPS part;

Fig. 2 is a schematic diagram of a combination GPS
satellite navigation receiver and communication device system
10 embodiment of the present invention in which the communication
VCO device's provides a reference frequency assist to the GPS
part and therefore eliminates a GPS crystal oscillator; and

Fig. 3 is a schematic diagram of a multiple re-use of
frequencies in a combination GPS satellite navigation receiver
15 and communication device system embodiment of the present
invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

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Fig. 1 illustrates a basic integrated combination of a
satellite navigation receiver and communication device system
embodiment of the present invention, and referred to by the
general reference numeral 100. The system 100 has two parts,
25 including a navigation receiver in the form of a global
position system (GPS) receiver 102, and communication device
in the form of a cellphone 104 that provides reference
frequency assistance to the GPS part 102. The GPS part 102 is
either a self-contained positioning model or a measurement
30 model with positioning code executed on a host CPU.

In general, the present invention provide for sharing of
oscillators to reduce the number of crystals and crystal
oscillators needed in the implementations, e.g., to save on
the manufacturing costs. In a mass production market, small

price reductions frequently results in significantly higher sales volumes.

In system 100, the GPS part 102 comprises a GPS patch antenna 106, a GPS-oscillator 108, a GPS RF-receiver 110, and a GPS digital signal processor 112. The GPS part 102 can simply take measurements and forward them to a host CPU for position solution processing, or process the position solutions itself. Sharing a highly capable host CPU with the cellphone part 104 provides a way to reduce overall costs.

The cellphone part 104 comprises a cellphone antenna 114, a communications transceiver 116, a cellphone digital signal processor (DSP) 118, a first oscillator (osc1) 120 that feeds a voltage controlled oscillator (VCO) 122, a second oscillator (osc2) 124, a third oscillator (osc3) 126, and a clock selector 128. A host CPU 130 provides high level functionality to both the GPS part 102 and the cellphone part 104.

Several crystal re-use and frequency sharing arrangements are possible in embodiments of the present invention. For example, the GPS part can be arranged to supply a reference crystal frequency to the phone part to re-use a crystal, e.g., to eliminate the need for a VCO crystal oscillator in the communications device. The GPS could also provide accurate frequency to the communications device to improve its acquisition and tracking of the communications VCO; or/and provide a phone processor clock in both nominal and high power consumption environments; or/and be used to source a frequency synthesizer to supply any continuous frequency within its generation range; or/and can supply time events to the host CPU 130 that are accurate GPS time events; or/and can supply time events in host CPU time frame via an offset from GPS system time; or/and can supply real-time-clock capabilities to host CPU.

The oscillators referred to herein include OscGPS 108 (Fig. 1) which generates all frequencies for GPS RF and digital processing. Osc1 120 produces a reference for the communications VCO and synthesizes all the RF frequencies
5 needed for the communications device, e.g., a high RF frequency and an intermediate IF frequency. The Osc2 124 produces "Fproc" as the normal operating frequency for the communications CPU, and Osc3 126 for low-power frequency "FprocLP" used for idle, standby or off times.

10 Fig. 2 illustrates another integrated combination of a satellite navigation receiver and communication device system embodiment of the present invention, and referred to by the general reference numeral 200. The system 200 has a global position system (GPS) receiver part 202, and a cellphone part
15 204 wherein the cell phone part 204 provides a reference frequency good enough to eliminate the need for a separate GPS crystal oscillator in the GPS part 202.

In system 200, the GPS part 202 comprises a GPS patch antenna 206, a GP-frequency synthesizer 208, a GPS RF-receiver
20 210, and a GPS digital signal processor 212. The GPS-synthesizer 208 eliminates the need of a GPS crystal oscillator, e.g., GPS-oscillator 108, by synthesizing the GPS reference frequency (Fgps) directly from the VCO frequency (Fvco). When Fvco is locked by the communications system
25 reference standards, the frequency is very exact and dependable.

The cellphone part 204 comprises a cellphone antenna 214, a communications transceiver 216, a cellphone digital signal processor (DSP) 218, a first oscillator (osc1) 220 that feeds
30 a voltage controlled oscillator (VCO) 222, a second oscillator (osc2) 224, a third oscillator (osc3) 226, and a clock selector 228. A host CPU 230 provides high level functionality to both the GPS part 202 and the cellphone part 204. The first oscillator (osc1) 220 is typically a

temperature compensated crystal oscillator (TCXO). The third oscillator (osc3) 226 is typically a 32-KHz real time clock (RTC) that can be based on a watch crystal.

One advantage of GPS is that high accuracy positions can be obtained even while depending on low cost crystal oscillator reference frequency sources. But problems can arise when the GPS reference frequency is derived from a communications VCO. Frequency jumps can afflict the GPS reference frequency when the communications VCO transitions between different cell towers, e.g., because of different base transmitter frequency offsets, and because the velocity vector to respective towers can be very different. The resulting delta-Doppler can be significant. There can also be residual uncompensated frequency errors in the automatic frequency compensation (AFC) frequency loop of the communications device. The communications device can tolerate larger frequency errors in comparison to the data rate that can be tolerated by the GPS receiver. Reducing the frequency that the AFC loop updates can be used to minimize data processing and CPU loading. The residual frequency error can increase when the communications device goes into standby mode with the frequency control in open loop and drifts uncorrected.

Frequency stability is important in communication systems, but the data rate is much higher than the typical frequency errors so it can still be properly demodulated. The data is detected at a much higher bandwidth than the low frequency VCO hold off error. Unlike the GPS part, precise carrier tracking is not needed as long as the data can be demodulated properly. When frequency updates are received, such are band limited to reduce jump inputs into the VCO. But, signal outages and tower changes will nevertheless introduce frequency errors during open loop operation that adversely impact the GPS operation.

High frequency changes in the reference frequency for the GPS affects searching, and not the ultimate accuracy of GPS position solutions. Some problems accompany using a GPS reference frequency derived from a VCO. A NavData collection error occurs if the frequency jump during the 20-msec period is more than a half cycle of the data bit and the data will not be decoded correctly. A frequency assistance error occurs if the VCO error is driven by tower frequency error, communications velocity, or loop error. The GPS receiver encounters error when trying to cross-calibrate with the communications device frequency, e.g., a frequency assistance method embodiment of the present invention.

Sensitivity loss can occur. Narrow band integration is preferred in high sensitivity GPS receivers. The VCO frequency error causes an error in GPS measurement. If it is common mode, it effects the GPS drift estimate. An error in such frequency estimate causes errors in the frequency prediction of where to acquire the satellite. Any error increases the amount of search required, thus delaying the fix. Frequency errors in tracking the GPS signal cause position errors for long measurement integrations required for high sensitivity. An error in frequency during long correlations spreads the energy across many pseudorange code phases. Thus, signal power is lost and the true peak is not known.

In a PDC-telephone network, the typical error budget includes 0.1 PPM base station stability, $100 \text{ mph} = 44 \text{ m/s} = 230 \text{ Hz} = 0.15 \text{ PPM}$, loop budget 0.2 PPM, all for total of almost 0.45 PPM. Therefore using a VCO as a frequency source for a GPS receiver is practical. On the other hand, modern low-cost TCXO oscillators are able to provide similar or better stability if software modeling is used.

Fig. 3 illustrates a multiple re-use of frequencies in an integrated combination of a satellite navigation receiver and

communication device system embodiment of the present invention, referred to by the general reference numeral 300. The system 300 has a GPS part 302 and a cellphone part 304 that are both integrated within the same portable or handheld
5 device. The GPS part 302 includes a GPS antenna 306, a GPS RF-receiver 308, a GPS digital processor and frequency generator (chip) 310, a GPS oscillator (oscGPS) 312, and a low frequency oscillator (osc3) 314. A clock selector 316 selects between normal and low-power operation, e.g., by clock
10 frequency choices. The cellphone part 304 includes a cellphone antenna 318, a communications transceiver 320, a digital signal processor 322, a phone CPU-power control-clock selector 324, a divider 325, and a voltage controlled oscillator (VCO) 326.

15 The divider 325 is included to increase the relative stability and accuracy of the reference frequency applied to VCO 326. The cellphone part 304 is not as dependent on its cellphone base station providing good reference frequencies for proper CDMA operation when it has very accurate references
20 locally. If all the mobile phones operating in a base station area had such GPS-provided reference signals, the base station would not need to be equipped with expensive atomic clocks.

Communication devices generally need their own faster processor crystals, since the typical VCO oscillator operates
25 in the relatively slow 10-13 MHz range. Some processors need to be able to switch to even higher frequencies for special communications functions. An intermediate frequency (IF) used in the down conversion process and produced in the RF chip can be used to run applications that require more computation
30 resources. A low frequency oscillator is selected for low-power time maintenance, and is typically a 32-KHz crystal.

At turn-on, the GPS chip 310 loads a default startup processor clock selection for the phone CPU 324, e.g., from a non-volatile memory location. The host processor clock

frequency is generated by multiplying GPS clock for input to a numeric controlled oscillator (NCO). Such NCO can then be digitally programmed to generate any output frequency up to half of its input frequency. The GPS part 302 puts itself
5 into a sleeping, low-power mode and lets the user decide when to use the GPS. A host system begins operating when its clock is stable. The host can then chose different frequencies, via the communication between the host CPU 324 and GPS digital chip 310. The phone part 304 can request a general frequency
10 number by sending a desired frequency. It can control when the VCO is turned onto the frequency to be used, e.g., 12.6MHz for the Japanese PDC system. If the GPS part 302 is tracking GPS satellites and solving for its frequency error, it can then compensate the requested 12.6MHz by what it knows to be
15 the error in the GPS crystal. Thus, it can provide a more stable frequency to the communications device VCO 326. If low-power mode is needed, the communications device 304 can request that the GPS part 302 enter low-power mode. It keeps time with the low frequency crystal input from osc3 314. If
20 the GPS oscillator 312 can be made low-power, the 32kHz oscillator 314 can be eliminated. The GPS part 302 can send interrupts to the phone part 304 on time-events lines to wake certain processes that need to occur at regular but accurate intervals.

25 The GPS part 302 provides a VCO frequency corrected by GPS satellite time standards, and is very accurate. A variable VCO from the GPS part 302 can be supplied that is responsive to requests from the phone part 304, e.g., for frequency stepping operations needed in frequency-division
30 multiple access (FDMA) systems. An analog sinusoidal voltage can be output by the GPS part 302 to approximate a crystal output. Such may be requested by using bits from the top of an adder for accurate phase. Such phase is converted with a table having more representative levels for a sinusoid rather

than the linear counter value. A table value can be converted to an analog signal in a digital to analog converter. The overflow of the adder can also be used to generate a simple 1-bit digital clock frequency. Time interval interrupts can be
5 constructed from combinations of the GPS second and millisecond interrupts in the GPS receiver, and osc3 314. The timing of events can be phased to any time frame of reference by using offsets.

In a method embodiment of the present invention, the
10 number of source oscillators in an integrated combination navigation receiver and cellphone is reduced to two, e.g., a GPS crystal oscillator at about 27-MHz and a watch crystal oscillator at about 32-KHz. A multiplier is connected to the GPS crystal oscillator to produce higher frequencies. Two
15 numeric controlled oscillators (NCO1 and NCO2) are used, respectively, to generate VCO and host CPU frequencies. A time event logic produces time events to the host CPU from combinations of GPS msec interrupts, GPS second pulses, digital offsets, and the watch crystal oscillator.

20 In general, embodiments of the present invention improve both manufacturing costs and device performance. For example, the navigation receiver supplies a reference crystal frequency to the communications device to re-use a crystal, thus eliminating the need for a second crystal, the communications
25 VCO crystal. And, when the navigation receiver supplies such reference crystal frequency to the communications device, the communications receiver sensitivity is improved because the frequency uncertainty is so much reduced the initial frequency search space can be trimmed. The receiver is thus able to
30 search for signal in the frequency domain using smaller increments or steps, but still be able to find initial lock in a reasonable time.

Although the present invention has been described in terms of the presently preferred SPS receivers, it is to be

understood that the disclosure is not to be interpreted as limiting. Various alterations and modifications will no doubt become apparent to those skilled in the art after having read the above disclosure. Accordingly, it is intended that the
5 appended claims be interpreted as covering all alterations and modifications as fall within the "true" spirit and scope of the invention.

What is claimed is: